

WHAT IS CLAIMED IS:

1 1. A class AB output circuit having an input terminal and an output terminal,
2 comprising:

3 (a) a P-channel first output transistor having a source coupled to a first supply
4 voltage, a drain coupled to the output terminal, and a gate coupled to respond to an input signal
5 on the input terminal, and an N-channel second output transistor having a drain coupled to the
6 output terminal, a source coupled to a second supply voltage, and a gate coupled to respond to
7 the input signal;

8 (b) a first N-channel transistor having a drain coupled to a gate of the first
9 output transistor and also coupled to the first supply voltage by means of a first current source
10 and a source coupled to the second supply voltage by means of a second current source;

11 (c) a first diode-connected N-channel transistor, a second diode-connected N-
12 channel transistor, and a first voltage level shifting circuit coupled in series between the second
13 supply voltage and a gate of the first N-channel transistor, and a current source coupled between
14 the first supply voltage and the gate of the first N-channel transistor; and

15 (d) a second voltage level shifting circuit coupled between the gate of the
16 second output transistor and the source of the first N-channel transistor.

1 2. The class AB output circuit of claim 1 wherein the first voltage level shifting
2 circuit has a first terminal coupled to a gate and drain of the first diode-connected N-channel
3 transistor and a second terminal coupled to a source of the second diode-connected N-channel
4 transistor, a gate and drain of the second diode-connected N-channel transistor being coupled to
5 the gate of the first N-channel transistor, a source of the first diode-connected N-channel
6 transistor being coupled to the second supply voltage conductor.

1 3. The class AB output stage of claim 2 wherein the first terminal of the first voltage
2 level shifting circuit is connected directly to the gate and drain of the first diode-connected N-
3 channel transistor.

1 4. The class AB output stage of claim 3 wherein the first terminal of the first voltage
2 level shifting circuit is indirectly coupled to the gate and drain of the first diode-connected N-
3 channel transistor by means of an operational amplifier having a first input connected to the gate
4 and drain of the first diode-connected N-channel transistor and a second input connected to the
5 first terminal of the first voltage level shifting circuit and an output coupled to provide feedback
6 control of the voltage of the second terminal of the first voltage level shifting circuit.

1 5. The class AB output circuit of claim 2 wherein the first supply voltage is positive
2 relative to the second supply voltage, and wherein the first and second terminals of the first
3 voltage level shifting circuit are (+) and (-) terminals, respectively, and wherein a (+) terminal of
4 the second voltage level shifting circuit is coupled to the gate of the second output transistor and
5 a (-) terminal of the second voltage shifting circuit is coupled to the source of the first N-channel
6 transistor.

1 6. The class AB output circuit of claim 1 wherein the input signal is coupled directly
2 to the gate of the second output transistor.

1 7. The class AB output circuit of claim 1 wherein the input signal is coupled
2 indirectly to the gate of the second output transistor.

1 8. A class AB output circuit having an input terminal and an output terminal,

comprising:

(a) a P-channel first output transistor having a source coupled to a first supply voltage and a drain coupled to the output terminal, and an N-channel second output transistor having a drain coupled to the output terminal and a source coupled to a second supply voltage;

(b) a first P-channel transistor having a source coupled to the output terminal and a gate coupled to the input terminal;

(c) a first N-channel transistor having a drain coupled to a gate of the first output transistor and also coupled to the first supply voltage by means of a first resistor and a source coupled to the second supply voltage by means of a second current source;

(d) a first diode-connected N-channel transistor having a source connected to the second supply voltage;

(e) a first voltage level shifting circuit having a (+) terminal coupled to a gate and drain of the first diode-connected N-channel transistor;

(f) a second diode-connected N-channel transistor having a source connected to a (-) terminal of the first voltage level shifting circuit; and

17 (g) a second voltage shifting circuit having a (-) terminal coupled to the gate
18 of the second output transistor and a drain of the first P-channel transistor and a (+) terminal
19 coupled to the source of the first N-channel transistor.

1 9. The class AB output circuit of claim 8 wherein the first voltage level shifting
2 circuit includes an operational amplifier having a (-) input coupled to the gate and drain of the
3 first diode-connected N-channel transistor and a (+) input coupled to the source of the second
4 diode-connected N-channel transistor.

1 10. The class AB output circuit of claim 9 wherein the (+) input of the operational
2 amplifier is coupled to the source of the second diode-connected N-channel transistor by means
3 of a first level shifting resistor having a first terminal coupled to the (+) input of the operational
4 amplifier and a second terminal coupled to the source of the second diode-connected N-channel
5 transistor.

1 11. The class AB output circuit of claim 10 wherein the second voltage level shifting
2 circuit includes a second resistor having a first terminal coupled to the gate of the second output
3 transistor and a second terminal coupled to the source of the first N-channel transistor.

1 12. The class AB output circuit of claim 11 including a second N-channel transistor
2 having a source coupled to the second supply voltage, a drain coupled to the second terminal of
3 the first voltage level shifting resistor, and a gate coupled to an output of the operational
4 amplifier.

1 13. The class AB output circuit of claim 12 including a third N-channel transistor
2 having a source coupled to the second supply voltage, a drain coupled to the second terminal of
3 the second voltage level shifting resistor, and a gate coupled to an output of the operational
4 amplifier.

1 14. The class AB output circuit of claim 11 wherein the resistance of the second
2 resistor tracks the resistance of the first resistor with respect to temperature.

1 15. The class AB output circuit of claim 13 wherein the output of the operational
2 amplifier performs the function of setting the voltage of the first terminal of the first resistor to
3 be equal to the voltage of the gate and drain of the first diode-connected transistor.

1 16. A method of operating a class AB output circuit at reduced power supply voltage
2 levels, the class AB output circuit including

3 an input terminal and an output terminal,

4 a P-channel first output transistor having a source coupled to a first supply
5 voltage, a drain coupled to the output terminal, and a gate coupled to respond to an input signal
6 on the input terminal, and an N-channel second output transistor having a drain coupled to the
7 output terminal, a source coupled to a second supply voltage, and a gate coupled to respond to
8 the input signal, a first N-channel transistor having a drain coupled to a gate of the first output
9 transistor and also coupled to the first supply voltage by means of a first current source and a

source coupled to the second supply voltage by means of a second current source,

a first diode-connected N-channel transistor and a second diode-connected N-channel transistor coupled in a series relationship between the second supply voltage and a gate of the first N-channel transistor, and a current source coupled between the first supply voltage and the gate of the first N-channel transistor,

the method comprising:

(a) shifting a first voltage level on the gate and drain of the first diode-connected N-channel transistor by a first predetermined amount to a first lower level and applying the first lower level to the source of the second diode-connected N-channel transistor; and

(b) shifting a second voltage level on the gate of the second output transistor by a second predetermined amount to a second lower level and applying the second lower level to the source of the first N-channel transistor.

17. A class AB output circuit for operation at reduced power supply voltage levels, comprising:

an input terminal and an output terminal,

a P-channel first output transistor having a source coupled to a first supply voltage, a drain coupled to the output terminal, and a gate coupled to respond to an input signal on the input terminal, and an N-channel second output transistor having a drain coupled to the output terminal, a source coupled to a second supply voltage, and a gate coupled to respond to the input signal, a first N-channel transistor having a drain coupled to a gate of the first output transistor and also coupled to the first supply voltage by means of a first current source and a source coupled to the second supply voltage by means of a second current source;

a first diode-connected N-channel transistor and a second diode-connected N-channel transistor coupled in a series relationship between the second supply voltage and a gate of the first N-channel transistor, and a current source coupled between the first supply voltage and the gate of the first N-channel transistor;

means for shifting a first voltage level on the gate and drain of the first diode-connected N-channel transistor by a first predetermined amount to a first lower level and applying the first lower level to the source of the second diode-connected N-channel transistor; and

means for shifting a second voltage level on the gate of the second output transistor by a second predetermined amount to a second lower level and applying the second

21 lower level to the source of the first N-channel transistor.

1 18. A voltage reference circuit comprising:

2 (a) a class AB output circuit including

3 i. a P-channel first output transistor having a source coupled to a first
4 supply voltage, a drain coupled to the output terminal, and a gate coupled to respond to an input
5 signal on the input terminal, and an N-channel second output transistor having a drain coupled to
6 the output terminal, a source coupled to a second supply voltage, and a gate coupled to respond
7 to the input signal,

8 ii. a first N-channel transistor having a drain coupled to a gate of the first
9 output transistor and also coupled to the first supply voltage by means of a first current source
10 and a source coupled to the second supply voltage by means of a second current source,

11 iii. a first diode-connected N-channel transistor, a second diode-connected
12 N-channel transistor, and a first voltage level shifting circuit coupled in series between the
13 second supply voltage and a gate of the first N-channel transistor, and a current source coupled
14 between the first supply voltage and the gate of the first N-channel transistor, and

15 iv. a second voltage level shifting circuit coupled between the gate of the
16 second output transistor and the source of the first N-channel transistor;

17 (b) a bandgap reference voltage circuit; and

18 (c) a feedback amplifier including a first input coupled to an output of the
19 bandgap reference voltage circuit, a second input coupled to receive a feedback signal produced
20 in response to an output voltage on the output terminal, and an output coupled to produce the
21 input signal on the input terminal.

1 19. The reference circuit of claim 18 including a feedback circuit including a first
2 feedback resistor and a second feedback resistor coupled in series between the output terminal
3 and the second supply voltage, the feedback signal being produced at a junction between the first
4 and second feedback resistors.